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should be ...

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6/8/59
9:00

June 2, 1959

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Attention: [redacted]

Dear [redacted] 25X1

Enclosed are three (3) copies of Report No. [redacted] This is the final report for this project. If there are any questions please feel free to call me. HIGH INTENSITY WHISTLE STUDY 25X1

Very truly yours,

[redacted] 25X1

3 encls.
MDB/es

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HIGH INTENSITY WHISTLE STUDY

to

[redacted] 25X1

June 1, 1959

Copy No. 1

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HIGH INTENSITY WHISTLE STUDY

I. INTRODUCTION

During World War II the German Air Force equipped dive bombers with pure tone whistles known as "Jericho Horns". These devices were reported by some observers to be very effective and by other observers to be ineffective in creating hysteria and other reactions in the populace. If the "Jericho Horns", which are called whistles in this report, were as effective as indicated they would be useful to the sponsor in certain applications. The present project was undertaken to determine some of the operating characteristics of these whistles and to learn whether they could be made to be as effective as reported.

Four whistles were constructed for laboratory and field study. Acoustic outputs were measured for the whistles operating in a reverberation room and for the whistle mounted on two airplane types at a country observation station. This report summarizes the design considerations for the whistles constructed and the performance obtained. Suggested operational procedures are given. It is concluded that there would be little to be gained in additional annoyance from an airplane capable of 300 mph flying at 300 ft altitude by adding whistles to them because the acoustic output is too low compared to an airplane's acoustic output.

II. WHISTLE DESIGN CRITERIA

It was desired that the whistle produce maximum acoustic output for an aircraft travelling in horizontal flight at around 300 mph, and 300 ft altitude. Maximum output in this case should be a signal which is clearly audible over the engine noise of the plane. Some mention was made of having the whistle sound levels approach pain thresholds but this is impractical in a free-field environment around a flying airplane.

The whistles are of the Edelmann[1] type, using the principle of an air jet impinging upon the edge of a resonant chamber. A basic unit (Fig. 1) has two primary components; the nozzle which accepts, compresses, and directs the airflow through an annular slit, and a cylindrical resonant cavity which incorporates an annular edge for the air jet to impinge. The frequency and sound power generated by the whistle depend on three variables: (1) the velocity of the air exiting from the jet, (2) the distance from the jet orifice to the edge, and (3) the

[1] M. Edelmann, Ann. d. Physik 2, 496 (1900).

dimensions of the cavity.

This whistle may be considered as a tightly coupled oscillating system, the cavity being the controlling element, and the jet of air being the driving element. Principle control of the frequency is obtained by adjustment of the cavity depth. For the operating frequency of 1000 cps, the cavity is approximately 3 inches deep, corresponding to a quarter-wavelength resonant condition. On the experimental whistles, cavity depth is variable, so that frequency may be controlled. Maximum acoustic output occurs when the length to diameter ratio is between 1.3 and 1.5 thus a cavity diameter of 2 inches was selected for the whistles.

The jet and edge portion of the whistle is a generator of pure tone sounds by itself, i.e., without a resonator present. The frequency of the jet-edge tone is inversely proportional to the distance from the jet orifice to the edge and directly proportional to the air velocity. There are several stable modes of tone generation and the sound output for each mode usually increases with air velocity. Any of the jet-edge modes may excite the whistle but there is usually one which produces a larger sound output than the others. As with most coupled systems the amplitude of the acoustic oscillations are greatest when the frequency of the driving part is at or near the frequency of the resonator. For optimum acoustic output, then, the distance from the jet orifice to the edge is adjusted so that its naturally occurring frequency would yield a high acoustic output in the vicinity of 1000 cps for the air velocities exiting from the jet orifice. This distance is 5/8 inch for these whistles. We are limited somewhat in selection of jet to edge distance because the air supply velocity is determined by the airplane speed.

Structurally, the whistles must be light and have sufficient rigidity to withstand air buffetting of airplane flight. The relative position of the annular jet and the circular edge of the resonator portion is critical and it was advisable to fasten both to a common I-beam to assure common reference for mounting. All parts of the whistles are made of aluminum except for the air velocity control mechanism. The latter device, shown in Figs. 2 and 3, was added to assure that the air velocity from the jet could be maintained at the correct value for aircraft speeds of 150 mph or greater. It consists of a camera iris, Eastman Kodak Part (Junior Iris Lens Adapter 3/4 inch by 3 inch dia.), equipped with flexible cables for remote control. The jet to edge distance and the cavity length were both adjustable for experimental purposes but would be pinned permanently at optimum settings for service use. A pitot tube was placed in front of the jet orifice to measure the total air pressure in the jet air stream; this was used to provide experimental measurement of the air stream velocity, and would be used in the

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field to adjust for optimum jet air velocity. The pressure measurement is made with the airspeed indicators shown on the left of Fig. 2; shutter opening is adjusted with the control box on the right. Two airspeed indicators were used in one set of observations utilizing two whistles simultaneously. The control box was convenient in that it was equipped with two suitable sections, one for controlling each whistle.

The whistle should be mounted so that natural turbulence and boundary layer effects near the skin of the plane do not affect the whistle performance. Mounting procedure should also be quick and simple. Auxiliary equipment required should also be readily available in the field. The whistle was mounted on a Twin Beechcraft (see Fig. 4) by riveting the I-beam to a piece of sheet aluminum which was, in turn, riveted to the fuselage. On a Cessna 182 the whistle was fastened to the landing gear with a clamp, shown in Figs. 2 and 3. On both craft, there were inspection plates or holes through which the shutter control and the pitot pressure tubing could be passed. A complete mounting of two whistles on the Cessna could be done in several hours.

III. WHISTLE PERFORMANCE

Two types of whistle performance evaluations have been made; laboratory and flight. Laboratory measurements were carried out in a reverberation room. By observing the sound pressure level in the room the total sound power output of the whistle is determined. A whistle was attached directly to the compressed air supply and sound power as a function of the whistle variables was determined. From these measurements a set of optimum operating dimensions were chosen, for which sould power as a function of total pressure in the annular jet stream in millimeters of mercury and jet velocity in miles per hour is plotted in Fig. 5. This is a smoothed curve of experimental data. Notice that the sound pressure in the reverberation room has a maximum of 134 db in the vicinity of 35 mm of Hg total jet pressure. This corresponds to an acoustic power output of 142 db re 10^{-13} watts. The peak in output is quite broad, however, so that the airflow is not critical.

The mode of whistle operation represented by the data in Fig. 5 is particularly stable. Sound power outputs as high as 153 db re 10^{-13} watts were obtained in the laboratory, but the operation was less stable and considered to be undesirable for rugged service use.

The primary concern is how loud will this whistle sound. Assuming, as is reasonable, that the whistle acts as a point source of sound when it is a few feet away, the relation between sound pressure level and sound power level is as follows:

$$SPL = PWL - 51 \text{ db}$$

where

SPL = sound pressure level at 100 ft, db re 0.0002 μbar
PWL = power level, db re 10^{-13} watts.

The above whistle should produce 91 db sound pressure at 100 ft or 81 db at 300 ft. This is a little louder than conversational speech levels.

Pitot tube measurements of jet air velocity in the laboratory have to be correlated with aircraft speeds because the air supply conditions are somewhat different. In the laboratory the air is fed into the whistle from a pressure tank so that a constant pressure head is available. On the airplane, the pressure builds up as a result of the momentum of the air. The velocity of the jet is proportional to the aircraft velocity. The actual relationship is given by Fig. 6. In this figure, observed total jet pressure is plotted as a function of the indicated aircraft speed. The measurements are taken for the air inlet with unrestricted area, i.e., with the shutter iris wide open. At a given airplane speed, any jet velocity lower in value than indicated by this curve may be obtained by shutting down the iris. Selection of operating conditions for field tests thus involves a selection of the jet air velocity which gives the optimum sound output for the whistle.

In the course of the experiments with the whistles mounted on the airplane attempts were made to increase the effective jet air velocity by adding scoops or funnels onto the front of the whistle. One scoop is shown at the front of the whistle in Fig. 4. These turned out to be ineffective, principally because of certain aerodynamic limitations. When free air is collected into a constriction such as exists when the air is passed through the jet, there is a stagnation pressure which limits the airflow. This stagnation pressure is roughly proportional to the velocity of the aircraft and very little can be done to alter it. As a result, experimental observations with and without air inlet scoops were essentially the same.

A number of observations of whistle output were made during the course of the project. For the first tests a whistle was placed under the fuselage of a

Twin Beechcraft. A picture of the installation is shown in Fig. . Tape recordings of the sound heard at a point on the ground were made and these tapes were brought into the laboratory for analysis. Subjectively, the whistle was audible in the background of the airplane motors being much more predominant as the plane departed. It was audible for at least a mile. Attempts to analyze the data in the laboratory were unsuccessful because the aircraft motors and propellers were so noisy that the single tone of the whistle could not be separated from the noise background. The sound levels from the whistle when the airplane was directly overhead were approximately 80 db relative to 0.0002 μbars. One set of flight data was taken with two whistles attached to a Cessna 182. This airplane was capable of speeds in the range of optimum sound output. Being a smaller plane with lower horsepower engine, the background noise was somewhat less than the Beechcraft but laboratory analysis was difficult to carry out. The whistles were relatively more audible than before because of the lower engine noise. However, they did not appear to be much louder subjectively than before. Two whistles operating simultaneously may produce up to 6 db more sound pressure level if they are perfectly tuned and operating in phase. This condition is difficult to obtain so that the whistles will usually be detuned thus giving rise to beats. These beats were observed because the whistles were purposely detuned. It will be noted that the sound level is about that predicted on the basis of the laboratory measurements in the reverberation room.

A whistle of this type is highly efficient in conversion of steady gas flows into acoustic energy. It is estimated that the whistle achieves efficiencies of the order of 12 per cent. To obtain comparable sound levels with an all-electronic system would require an electronic amplifier capable of approximately 1000 watts output. This amplifier would have to supply its energy to loudspeakers. Both the amplifier and loudspeaker are an appreciable weight and volume load to be applied to an airplane.

IV. OPERATIONAL PROCEDURES

Although the development of the whistles has not been carried to the state in which they are ready for field use, a description of the arrangement and application can be given. The only variable feature to be incorporated into the whistles is the iris or shutter for restricting the area of the air inlet. The total pressure section of a conventional airspeed indicator would be connected to the pitot tube on the whistle. The static inlet to the airspeed indicator would operate at ambient atmospheric pressures and thus would be left open. Performance curves would be furnished which would relate airspeed indicated on this auxiliary indicator to the indicated airspeed of the airplane. When an operator desires to fly at a particular speed he looks at a curve such as Fig. 6 and determines the pitot velocity which he must maintain by adjusting the opening of the iris. The actual jet velocity is indicated by the curve in Fig. 5, which relates sound power output from the whistle to the air jet velocity. The attachment of the whistle to the airplane appears not to be particularly critical, although it is necessary to assure that the whistle is parallel to the flight axis of the plane. The control cable for the iris and the copper tube for the pitot pressure indicator may be extended along the exterior of the airplane and inserted into the airplane at any convenient location. It is desirable that they be tied to the fuselage, however, to prevent excessive vibration. No difficulties should be encountered in use of the iris if it is kept free of moisture and silicon type grease is used for lubrication.

V. CONCLUSION

The whistle does not produce as loud sounds as the sponsor had originally hoped. It is, however, a highly efficient device for generating pure tones from a flying aircraft. The sound is equivalent to a slightly louder than normal conversational level but is not of sufficient intensity to be particularly alarming. One observer commented that it sounded as if something was coming loose from the airplane and was going to be flying off any minute. This appears to be the most useful annoyance feature of the whistles. If the whistles were applied to an airplane which had a routine mission it would very readily identify it and might in this way become an annoyance. However, as an occasional operation it appears that very little would be gained.

The whistles constructed are very simple and are quite easily installed on aircraft. The operating procedures are simple and should not burden a pilot unduly.

A somewhat more expensive approach which might be considered for such devices is a combination of air scoop device such as this whistle employs but incorporating an electronically driven mechanical modulating element. Experimental work indicates that the conversion of electrical power to acoustic power can be very nearly the theoretical maximum. The conversion of the aerodynamic power to acoustic power is quite good also. The electrical package can be made from a completely transistorized system. The airstream modulating element would not be appreciably larger than the whistle which was built for this work.

VI. CONTRIBUTING PERSONNEL AND NOTEBOOKS

The work was carried out under the direction of [redacted] with assistance from [redacted] The data for this program is recorded in [redacted] Notebook No. 8152.

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Respectfully submitted,

[redacted]

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APPROVED:

[redacted]

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[redacted]

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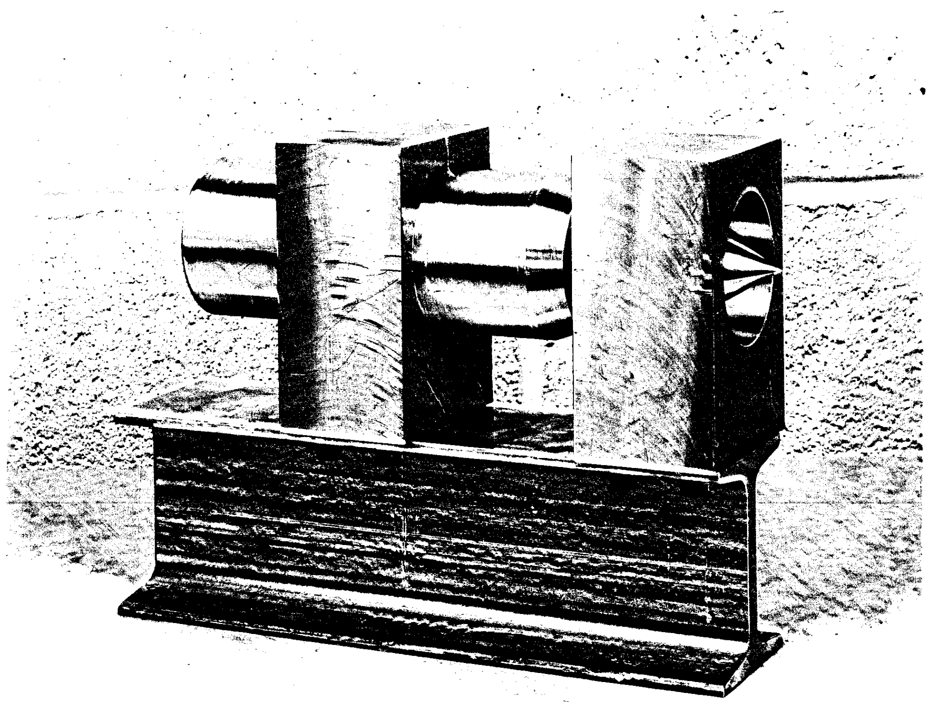

Fig. 1 - Basic Whistle Unit

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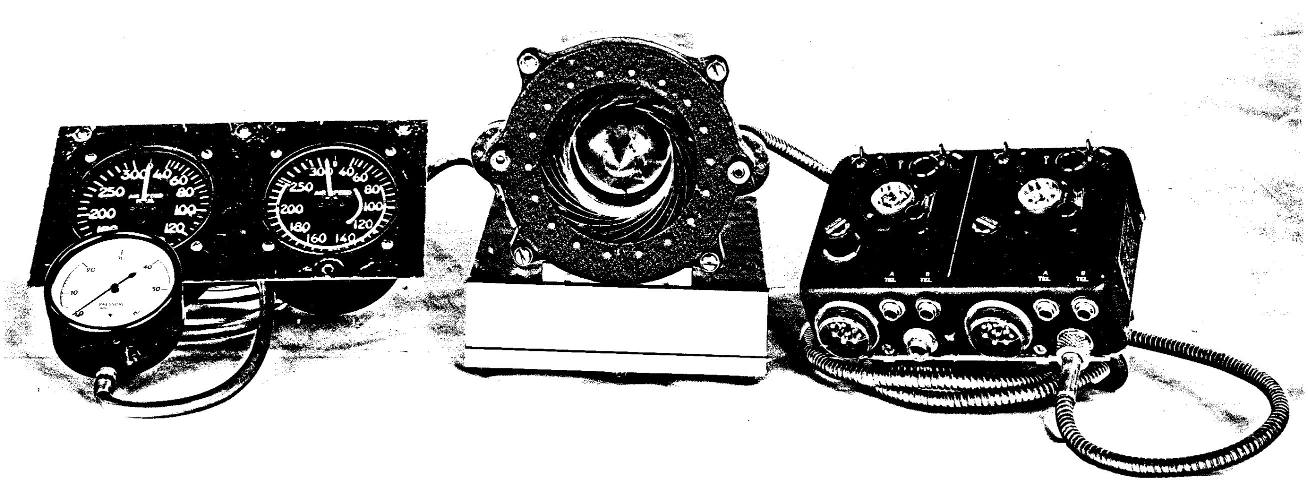

Fig. 2 - Flight Model with Measuring Indicators

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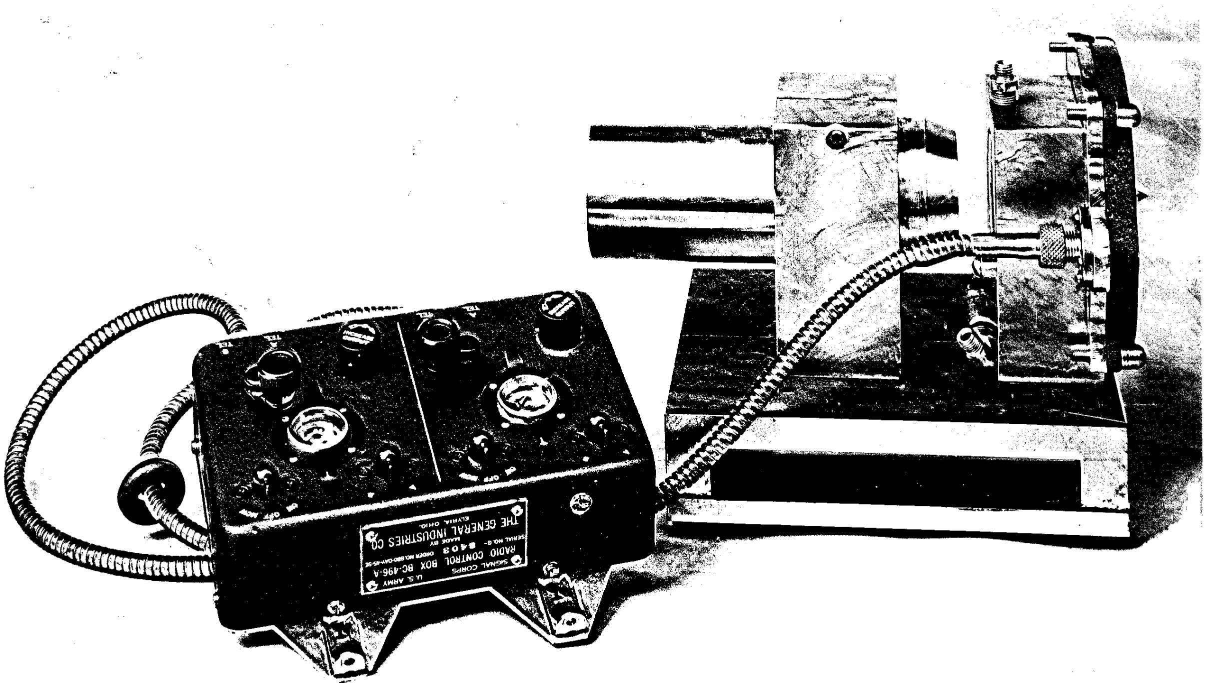

Fig. 3 - Iris Control Mechanism

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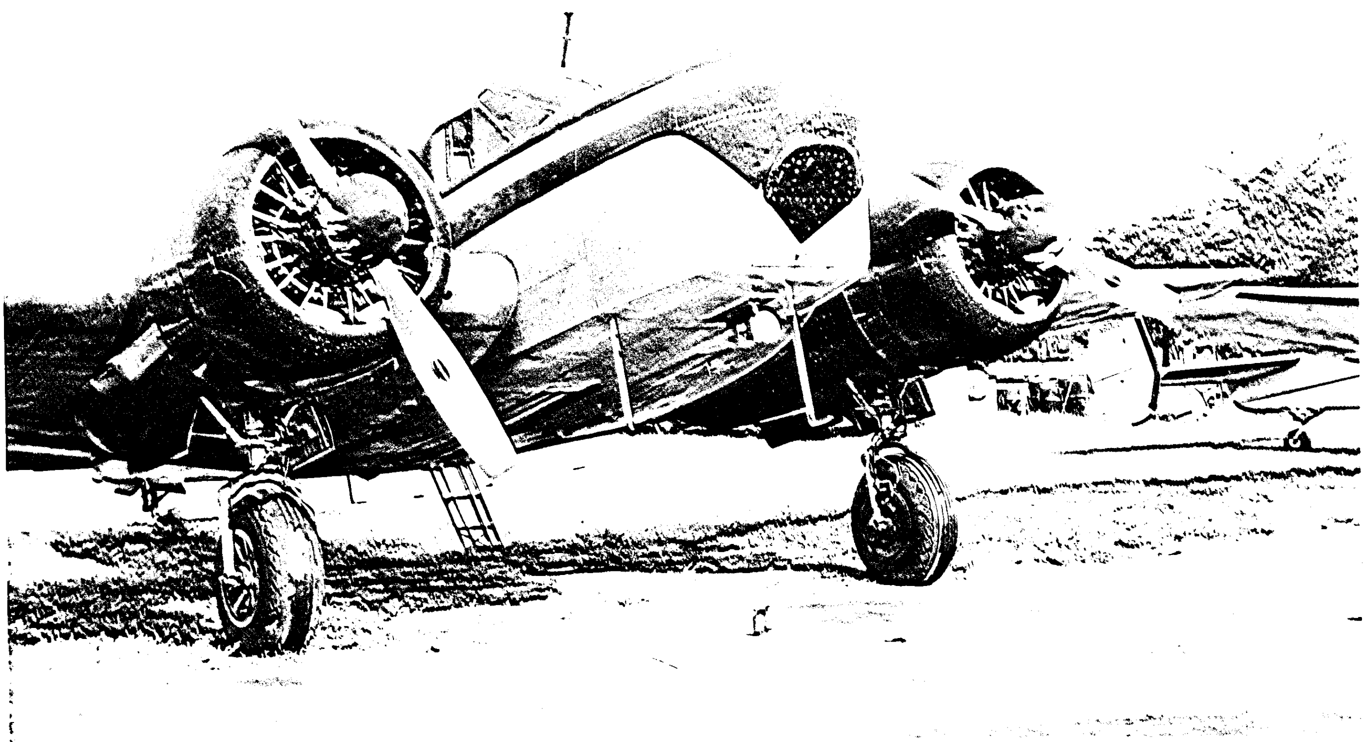

Fig. 4 - Twin Beechcraft used for Early Experimental Tests

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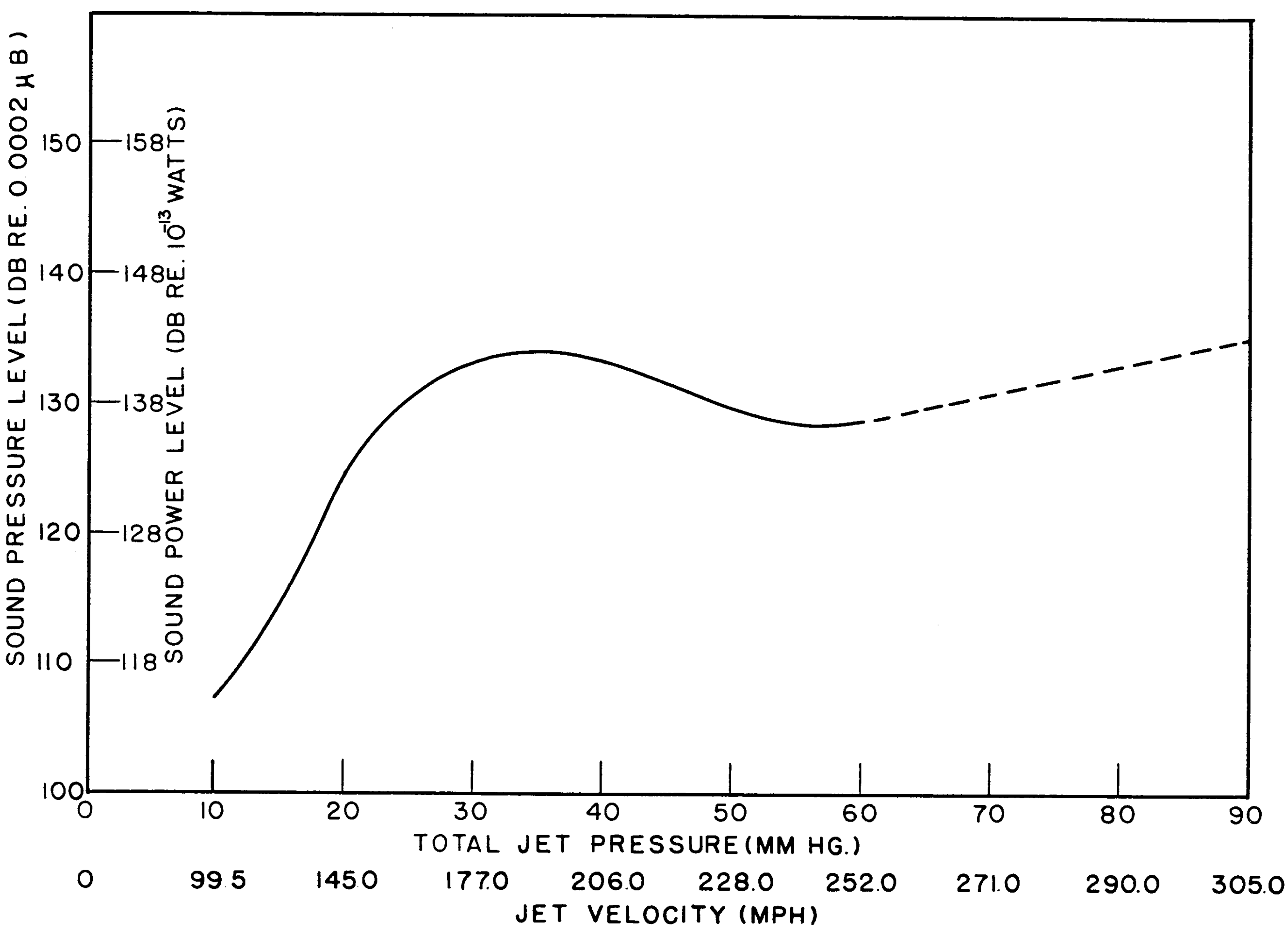

Fig. 5. Sound output of experimental whistle. These levels were measured in a reverberation room. The curve is a best fit to data. Jet velocity is computed from total jet pressure measured with the pitot tube.

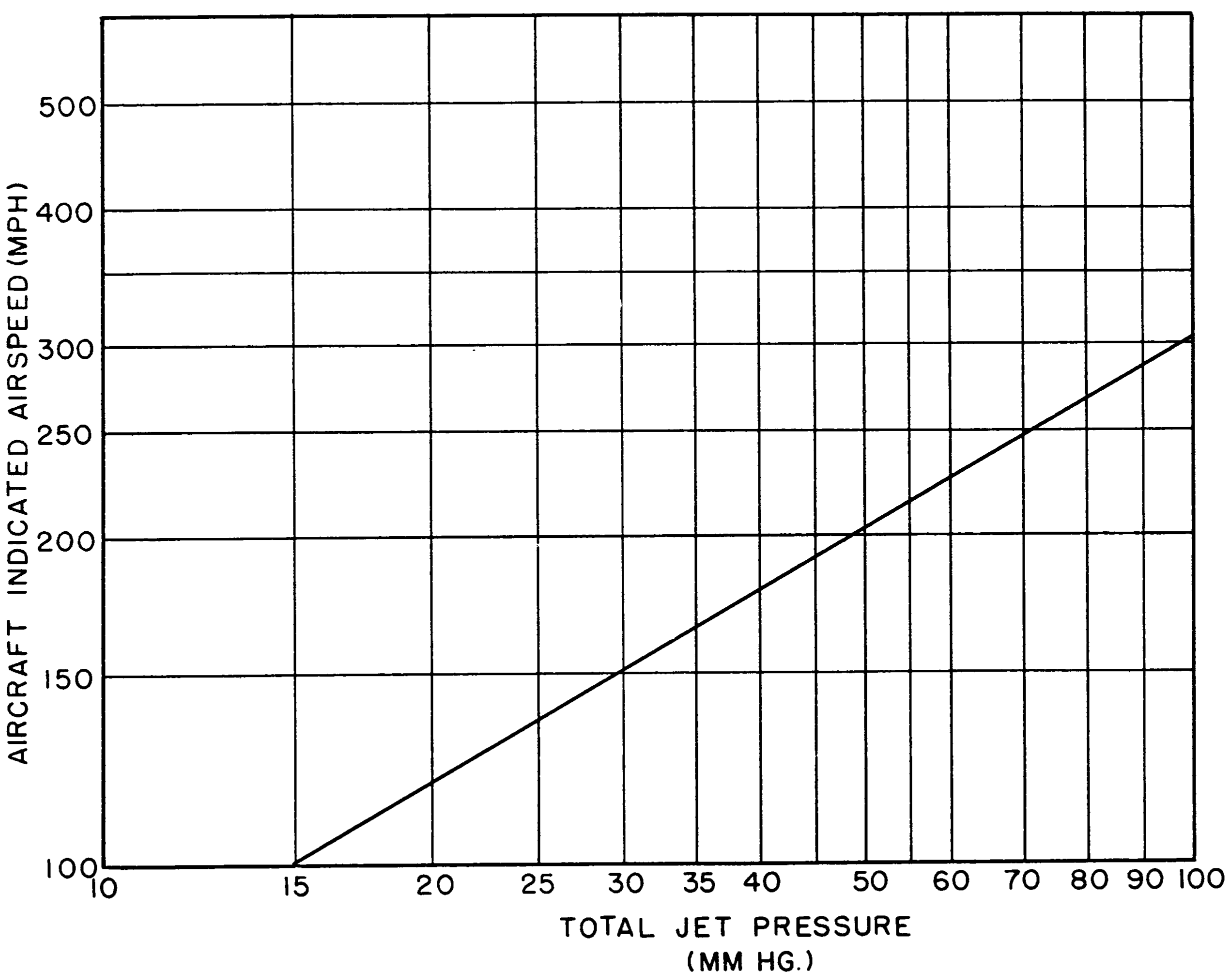

Fig. 6. Relation of aircraft indicated airspeed to total jet pressure measured with pitot tube.

29 November - Date Due

Marine outfit -
2 miles -
24 Volt - 10 days AT order

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De Havilland
L-20
M&C. Rec. [illegible] size

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landing gear motor

[redacted] - 25X1

TEC -3978 Try around noon

Thursday is their best day

[redacted] leave message w/ anyone in office. 25X1

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[illegible] in catalog

Size of plate

Mounting should be no problem

5 lbs - Approx. wt.

4" diam. motor

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ED-188C AIRCRAFT EQUIPMENT AIR WHISTLE [redacted]
~~ED-187~~ ~~HARASSMENT~~ ITEMS, ~~GENERAL~~

REQUESTED BY: MEMO FOR ENGRG DIV. DATED 12 MAY 58 FROM C/FE DIV. SUBJ: AIRBORNE "SCREAMER".

8 Sept 58: Initiated Task S/RD 33, [redacted], $6,572. 3 mos. 25X1

JAN 59 - REPORTED flight testing to be conducted shortly. Four units to be available for [illegible].

31 MAR 59 - Memo to C/FE Div Attn: [redacted] FE/[redacted] outlining that air whistle does not meet requirement and asking further guidance or proj will be dropped. 25X1 25X1

3 APR 59 - [redacted] indicated review of WWII [illegible] studies would have precluded further consideration of the air whistle to hurt physically by noise alone. 25X1

15 APR 59 - [redacted] FE/[redacted] returned 31 Mar 59 memo indicating concurrence with dropping the project and recommended that DPD be advised two prototype whistles are available. 25X1 25X1

1 JUL 59 - REPORTED an air whistle similar to that used by the Luftwaffe on the "stuka" bomber developed. Two complete devices available.

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